The Journal of HEREDITY

MIRROR-IMAGES IN HANDEDNESS

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Genius-in-the-Making

Teeth Lacking Enamel

Nobel Prize Awarded to Dr. T. H. Morgan

Foot-Length in a Species Cross

Origin of the Seedless Grapefruit

VOLUME 24 NOVEMBER, 1933 NUMBER 11

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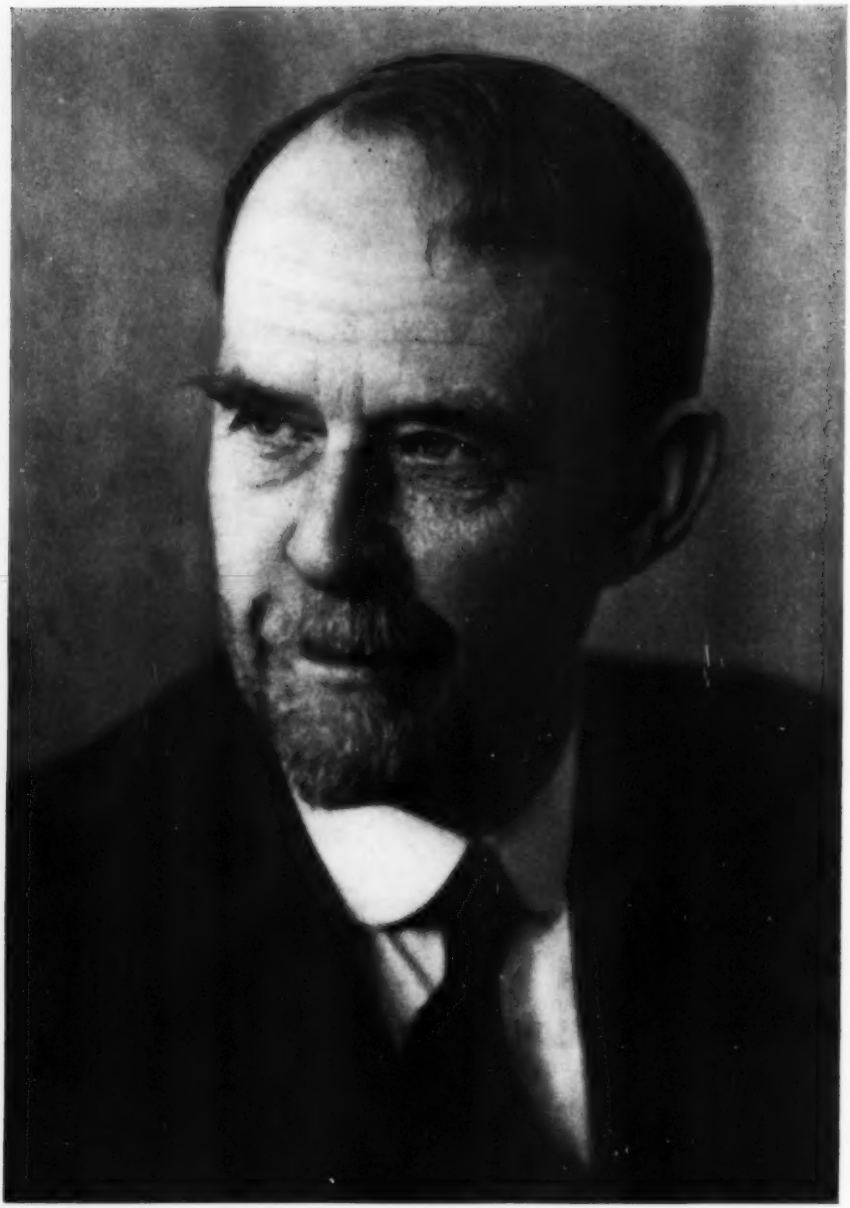

THOMAS HUNT MORGAN—AWARDED THE NOBEL PRIZE IN MEDICINE

Frontispiece

For his fundamental discoveries regarding the physical basis of heredity Dr. Morgan was awarded, on October 20th. the 1933 Nobel Prize in Medicine and Physiology.

GENIUS

A Review of the "Promise of Youth"—A Progress Report of a Thousand Gifted Children*

ALEXANDER WEINSTEIN
Department of Zoology, The Johns Hopkins University

GENIUS was formerly considered so incomprehensible that it was attributed to the prompting of a god or spirit. The word genius in fact once meant a guardian spirit, and we still speak of great actions as being inspired although we no longer take these terms in a literal sense. The belief in a supernatural origin of genius possessed a certain plausibility when the mental traits of all men were supposed to be genetically equal or nearly so; for many of the manifestations of genius could not be attributed to training or to other known environmental causes.

The doctrine of genetic mental equality is usually associated with the sentimental romanticism of the eighteenth century; but it is really older and it has been held not only by sentimentalists but by some of the world's greatest scientists. For example, Descartes began his *Discourse on Method,* which was published in 1637, as follows:

> Good sense is, of all things among men, the most equally distributed; for everyone thinks himself so abundantly provided with it, that those even who are the most difficult to satisfy in everything else do not usually desire a larger measure of this quality than they already possess. And in this it is not likely that all are mistaken: the conviction is rather to be held as testifying that the power of judging aright and of distinguishing truth from error, which is properly what is called good sense or reason, is by nature equal in all men; and that the diversity of our opinions, consequently, does not arise from some being endowed with a larger share of reason than others, but solely from this, that we conduct our thoughts along different ways, and do not fix our attention on the same objects.[1]

And Charles Darwin wrote in a letter to Francis Galton:

> I have always maintained that, excepting fools, men did not differ much in intellect, only in zeal and hard work; and I still think that this is an *eminently* important difference[2, 3].

Undoubtedly Descartes and Darwin were correct to a great extent, but not entirely; for there is evidence that men differ in understanding as well as in interests and industry, and in any event interests and industry themselves may be genetic. The widespread recognition of these facts is due to Francis Galton. How far ahead of his contemporaries he was in this respect is shown by the fact that his conclusions, although based on the theory of evolution, struck both Darwin and Wallace as highly original. Darwin, when he read *Hereditary Genius,* was convinced of the importance of heredity in mental traits; but others responded less quickly. The psychologists, for example, defined instincts as inherited modes of behavior; yet in the lists of instincts they drew up it seems never to have occurred to them to include intelligence.

If genetic differences in mentality exist, they must be found among psychologists themselves as well as among their subjects. It becomes necessary therefore to inquire how far the traits of an experimenter enter into the results of his observations and conclusions. It may be well in this connection to recall the attempt of Hamilcar the cat, in Anatole France's *Crime of Sylvestre Bonnard,* to compare his mas-

*THE PROMISE OF YOUTH. Follow-up Studies of a Thousand Gifted Children. By Barbara Stoddard Burks, Dortha Williams Jensen, Lewis M. Terman. Assisted by Alice M. Leahy, Helen Marshall, Melita H. Oden. Stanford University, California: Stanford University Press, 1930. Pp. xiv+508. (*Genetic Studies of Genius,* Edited by Lewis M. Terman. Volume III).

ter the Academician with the housekeeper:

> This old book-man talks to no purpose at all, while our housekeeper never utters a word which is not full of good sense, full of significance—containing either the announcement of a meal or the promise of a whipping. One knows what she says. But this old man puts together a lot of sounds signifying nothing.

I do not mean any disrespect to the psychologists. If a cat can look at an Academician, a psychologist can examine one of his own fellow-men; but the limitations of the observer must be taken into account, especially when he is dealing with genius.

Psychological Tests of a Thousand Gifted Children

Galton's studies of genius were based on men who had already achieved distinction. Professor Terman and his co-workers have begun at the other end: they are studying a group of gifted children to discover how these will develop in later life. This is a very necessary experiment; it touches on many important problems of human biology; and it is almost the only one of its kind that has been undertaken, at any rate on so large a scale. It is therefore bound to arouse wide interest. Unfortunately it is the fate of such work (as in the case of Galton) to have its conclusions quoted and the qualifying statements of the authors ignored. Hence it seems well to emphasize (what the authors are aware of) that the conclusions are as yet tentative, both because there are difficulties in observation and interpretation and because the experiment is far from completed. The authors hope to continue it "for another twenty years, by which time the majority of the children will be approaching the middle period of life." The very importance of the work renders desirable as critical an analysis as possible.

Most of the gifted children were selected in the first place by teachers who picked the youngest or ablest in their classes. From those so nominated and some others a thousand were chosen on the basis of their performance in psychological tests. The picked individuals were studied with respect to their physique and health, their interests and work in and out of school, their relatives and home environment. The results of the first tests, made in 1921-22, were published in volume I of the series in 1925; the present volume contains an account of a follow-up study made in 1927-28. It is divided into three parts: the first is an account of the group as a whole, the second a consideration of some especially interesting individuals, the third a study of literary juvenilia and a comparison of these with the juvenilia of great writers of the past.

In 1927-28 the Stanford Binet tests could be repeated on only fifty-four children because the others were almost all over thirteen years old, and the tests are not well standardized above that age. To get around this difficulty, other tests were used: 399 of the children above thirteen were given Terman Group tests and the results were interpreted on the basis of the known correlation between these tests and the Stanford Binet. There are, as the authors realize, difficulties with such a procedure; but after making allowances they conclude that on the whole the gifted children have maintained their superiority. The authors are inclined to regard this relative constancy of the intelligence quotient as an indication that it is not much influenced by environment. Such a conclusion, however, does not necessarily follow; for (1) the environment may have been relatively constant and probably was in some families, and (2) it is possible that the environment may produce at an early age effects difficult to reverse, so that subsequent changes in environment may be less effective.

The intelligence quotients however were not absolutely constant: in some individuals significant variations occurred. The authors can find no correlation between such changes and health, race, personality, or environment. Hence they consider it probable that the changes are due primarily to

"change of rate" factors which are presumably genetic. This is a possible interpretation, but it is not demonstrated; and again the results do not rule out environmental influences, for it is difficult to be certain that all elements of the environment have been examined, especially since field workers have only very limited opportunities for observation. It has in fact been shown in other investigations that the intelligence quotient can be affected by environment.*

The elimination of environmental differences is therefore a necessary prerequisite to a demonstration that intelligence quotients measure genetic traits. Such a demonstration however would still leave unanswered the questions what the traits are and how they are related to intelligence. It is by no means obvious that they are identical with intelligence, for the tests are largely empirical and there is no general agreement on what intelligence is. The problem can be attacked by comparing the performances of individuals in psychological tests with their achievements in other activities such as school studies or the work of adult life. Comparisons of this kind are the fundamental aim of *Genetic Studies of Genius.*

In school studies the gifted children were found to excel unselected children. This in itself would not prove that the intelligence quotient is a measure of scholastic ability, for most of the children were selected from among the best students in the first place. In fact, some of the children with poorer scholastic records were found to have equally high intelligence quotients, but a systematic search disclosed few such individuals and the authors conclude that the tests are a good indication of success in school work.

The children were also rated with respect to non-intellectual traits, such as "personality." The significance of these ratings is doubtful because the traits are difficult to measure and we can not be certain of the impartiality of the judges, who included parents and teachers. The data do not indicate to what extent these traits are environmental or genetic; but the studies of Muller[8] and of Newman[10, 11] on identical twins reared apart show that the environment exerts an important influence.

Although most of the children are still too young to have started on their life-work, their plans for careers have been rated on the basis of what is known as the Barr scale of occupational status.† In this scale one hundred representative occupations are arranged according to the amount of intelligence supposedly required for their successful pursuit. The order was determined by combining the opinions of thirty individuals presumably competent to act as judges, and in this way the personal equation is supposed to have been eliminated. Nevertheless the validity of the scale is very doubtful. The standard seems to be largely financial, although it has never been demonstrated that the operation of a large business on large resources requires more intelligence than the operation of a small business on small resources. In fact, the first million dollars are proverbially the hardest to make. A financial standard might be a criterion of intelligence if all men had equal opportunities of amassing wealth and were equally desirous of doing so; but both of these conditions are contrary to fact.

It is true that the financial standard of the Barr scale is tempered by some consideration for intellectual matters; but here there are curious discrepancies. It is hard to see why, on a purely intellectual basis, a hobo should be placed at the bottom of the scale, why an osteopath should be ranked above a teacher, or a skilful surgeon above a research leader like Binet or Pasteur.

Moreover, the intelligence used in following a vocation must be distin-

*See items 1, 2, 5, 7, 10, 11 in the bibliography below.

†The Barr scale is given in *Genetic Studies of Genius,* volume I, pages 67-69.

guished from the intelligence used in its choice. The choice may be forced by poverty, lack of educational opportunity, or insistence of parents; or it may be influenced by social, ethical, esthetic, or other emotional considerations. The father of one of the gifted children gave up farming to work in a university town as a laborer (supposedly a lower occupation) in order that his children might attend the university. Robert Burns, who was a farmer and exciseman, declined to consider positions that would have been rated near the top of the Barr scale. Spinoza, who made his living by grinding lenses, refused a professorship of philosophy at Heidelberg. Many men have chosen routine occupations in order to pursue their interests as avocations.

A Comparison of the Gifted Children with Great Men of the Past

The authors, while waiting for the gifted children to grow up, have compared their traits with those displayed in childhood and youth by great men of the past. This method was used in the second volume of *Genetic Studies of Genius* by Dr. Catherine M. Cox, and it is used again in the present volume in Dr. Jensen's study of literary juvenilia.

Dr. Cox attempted, with the cooperation of several other psychologists, to measure the intelligence of three hundred famous men and women up to the age of seventeen, and again for the years between seventeen and twenty-six. Many of these ratings fell considerably below 140, which is the minimum for the California gifted children; but Dr. Cox ascribed this to lack of information and concluded that a selection based on psychological tests would have resulted in the inclusion of the three hundred geniuses. The converse of this, as she pointed out, has not been proved; that is, we do not know that all children with intelligence ratings as high as those of the three hundred geniuses would have achieved greatness under similar conditions.

Dr. Jensen found the best literary work of the gifted children to be almost as good as the best juvenilia of twenty-eight famous English and American writers up to and including the age of nineteen. Her conclusion is based on the opinions of seven university teachers of English, psychology, or education.

This method raises many questions of which only a few can be discussed here. The intelligence ratings of the three hundred geniuses are not intelligence quotients in the strict sense, since they are not based on psychological tests; and to estimate intelligence quotients on the basis of them introduces an error whose magnitude is unknown. The fact that the intelligence ratings vary directly with the amount of information available about the subject might seem at first sight to support the validity of the method, since the records should be most numerous where there are the greatest number of remarkable traits to record. That the result is however influenced by other factors is suggested by the low ratings of some of the greatest men and the small amount of information available about them. The explanation is that the amount of information depends not only on what there is to record but on the likelihood that it will be recorded; and this depends on such matters as the wealth and culture of the family, the ability of parents, teachers, and others to recognize exceptional qualities, and the nature of the qualities themselves. Newton, whose rating is given as 130 for the first seventeen years of his life, came of a family that was not rich. His father, a farmer, died when the son was young; and under the circumstances scientific ability could have had little opportunity to manifest itself and to be appreciated. In contrast with this, Macaulay, whose rating for the same period is given as 180, came of a wealthy family. His father, a fellow of the Royal Society, took great interest in the boy's development; and Macaulay's exceptional traits (such as his prodigious verbal memory) were

of a kind that easily attracts attention and recognition. It is significant that the highest rating for the first seventeen years, 190, is that of John Stuart Mill, whose training was probably the most systematic and thorough ever given a child and whose traits (partly as a result of the training) were such as to be easily appreciated by his associates.

The discrepancies due to lack of information are increased by the fact that the judges deliberately gave higher ratings to individuals from the higher social classes. This was done on the assumption that intelligence varies with social status. Whether or not the procedure is justifiable, the ratings, being based on the assumption, can not be used as evidence in its favor.

The estimates of intelligence are affected not only by the amount of information but by its correctness as well. Biographical accounts are often unreliable because of the fallibility of memory, the bias of biographers or their informants, the desire to point a moral or to produce an artistic rather than an accurate portrait. A common practice is to attribute to one man the achievements of others in his field, and many eminent men are important as symbols rather than for any accomplishments of their own. This is exemplified in the clustering of medieval legends about the names of Alexander the Great, King Arthur, and Charlemagne, but it is not limited to the middle ages or to romance. Many biographies are official, being written by friends or relatives or under their supervision. When death removes the censors, it removes also sources of information. Autobiographies, too, are notoriously unreliable, as can be seen from the fact that two men as different as Nero and Keats are said to have summed up their lives in almost identical terms. Keats said "I think I shall be among the English poets after my death"; and Nero, "How great a poet dies in me."

These difficulties are illustrated in the estimate of Pope. His rating, 140, is based partly on the *Ode to Solitude*, which is accepted by Dr. Cox and Dr. Jensen as having been written in his twelfth year. Now the version they quote was published when Pope was forty-seven. It differs considerably from the version which, at the age of twenty-one, he transcribed in a letter to a friend, saying he had just discovered it "by great accident" and found "by the date" that it had been written before he was twelve years old. Nor is it likely that the earlier version was sent without revision, for Pope polished even the verses of his maturity; and in fact the manuscript bears marks of erasures and alterations. Moreover, the date of the original composition can not be accepted on the word of Pope, who when he published his letters modified them even to falsifying dates, combining parts of different epistles, and readdressing them to persons to whom they had never been sent. These facts are given not to raise the question of Pope's morality but to illustrate the difficulties involved in obtaining reliable biographical information.[12]

Dr. Cox admits that the "IQ scores are estimates of paper records only" and that they can "contribute to a study of the true mental level reached by great men in childhood . . . . only approximately" (vol. II, page 49). It should be added that since the accuracy of many records is unknown, the reliability of the approximation is often impossible to calculate.

Another difficulty of the method is that "all of the scores are dependent on the experience and the interpretation of the judges who assign them" (volume II, pages 48-49). The knowledge and discrimination required to judge some of the men correctly are very great and highly specialized. For example, Newton's intelligence can be accurately estimated only by those who are familiar with mathematics, physics, and astronomy and with the state of these sciences in his day. The judges assigned to Newton an intelligence quotient of only 170 in the years from seventeen to twenty-six; yet in

this period (as Dr. Cox herself states) he discovered the calculus, formulated the theory of gravitation, and laid the foundation of his work in optics.

The same difficulty occurs in esthetic judgments. In Dr. Jensen's study of literary juvenilia in volume III, Pope's *Ode to Solitude* is placed midway between the best and the worst youthful writings, in a class considered to be "as good as the average work appearing in modern popular magazines such as *Good Housekeeping, American, Saturday Evening Post,* etc." How correct this estimate is I can not say, since I do not read these journals. The rating can however be compared with the opinions of professional literary critics: for example, Francis Turner Palgrave, who included the poem in his *Golden Treasury*. Palgrave was professor of poetry at Oxford, he had in his compilation the advice of Tennyson, and his anthology has become a classic; so that his judgment is not merely that of a single individual. Now the *Golden Treasury* was designed to contain "all the best original lyrical pieces and songs in our language . . . and none beside the best." Hence if both Palgrave and the present judges are right, it follows that the average work in *Good Housekeeping,* the *American Magazine,* and the *Saturday Evening Post* is as good as the best in the English language up to the time of Palgrave. It seems to me much more likely that at least one of the opinions is wrong. I do not mean to imply that the error is necessarily on the part of the present judges. Palgrave was not infallible, and he may have been led astray by a desire, perhaps subconscious, to include something by Pope who (not being primarily a lyric poet) is otherwise unrepresented in the *Golden Treasury*. For our present purpose it is sufficient that two composite opinions, each held by presumably competent critics, are inconsistent with each other.

Thus here as elsewhere we are confronted with the problem of the validity of standards. This problem is not solved by statistical coefficients of the reliability of ratings. Such measures tell us how consistent the different judgments are with one another or with an average, but not how they would compare with the opinions of other judges or with a possible objective standard. The problem of the validity of standards is difficult and will lead far from the traditional fields of biology; but it must be solved if the significance of studies like those we are considering is to be decided.

The Frequency of Genius and Its Relation to Race, Class, and Sex

In spite of the difficulties, future work will, I think, corroborate the main conclusion of the authors, that "the world's supply of genius is probably many times as great as it would be judged to be from the amount which comes to light" (page 481). Certainly this is in accord with many everyday observations. The California data do not answer the question how genius is distributed among various races; but it is suggestive that the gifted children come from many subdivisions of the white race and include Negroes and Japanese-white hybrids as well. Few are known to come from the "lowest" occupational classes. In the first volume this was interpreted to mean that differences between such classes are genetic, since they appear early:

> There is one respect in which the contribution of the present study is unique. Earlier investigations had proved nothing more than that the upper social strata are more productive of men and women who have succeeded in achieving eminence. It has often been argued that this superiority in achievement should be credited for the most part to the larger opportunity for achievement enjoyed by members of the favored classes. *Our data show that individuals of the various social classes present these same differences in early childhood, a fact which strongly suggests that the causal factor lies in original endowment rather than in environmental differences.* (Vol. I, page 66; italics in the original.)

This argument rests on assumptions that are not demonstrated. (1) The differences between the thousand gifted children and others are not known to be the "same differences" as those be-

tween eminent and non-eminent adults. (2) Differences that appear early are not necessarily genetic: a child of three or four has already been exposed to many environmental influences that vary with social status. In volume III the authors speak with less assurance; they do not repeat their earlier statement but say, "However the fact is explained, gifted children are only rarely found in the lowest occupational levels" (page 219).*

Mental differences were found between boys and girls; but the interpretation of these is uncertain because the environment is probably never the same for the two sexes even within a family. A masculinity-femininity test showed gifted girls to be significantly more masculine than average girls, gifted boys slightly more feminine than average boys. This suggests that many mental differences between males and females are inculcated by environment, since presumably the gifted children are intellectually more independent than the average. Additional evidence is the fact that in the traits in which the gifted boys are more masculine than control boys, the gifted girls are more masculine than control girls; and similarly for deviations toward femininity. The seven children who produced the best literary work are all girls—another fact difficult to explain on the hypothesis that mental differences between the sexes are mostly genetic.

The Future of the Gifted Children

The future development of the children will be followed with interest. Those old enough to have started on careers include a university professor and a well-known musician; but others have failed to distinguish themselves. A few have been convicted of crimes and one has committed suicide.

It is of course certain that only a small proportion of the gifted children will fulfil the promise of their youth; for otherwise, as the authors say, "we might expect in ten or fifteen years, from our thousand California gifted children, such a crop of geniuses as has never before graced the population of a single state" (page 24). As civilization is now constituted, there is simply no outlet for most of the mental ability that exists, just as there is none for most of man's physical strength and agility. The question then arises, on what basis the successful individuals are selected. The authors attribute failure to various environmental circumstances, such as poverty, unwise educational guidance, accidental personal contacts, etc. (page 481); and to "personality traits and other non-intellectual aspects of endowment" (page 24). They mention specifically "personality defects" (page 481). Unfortunately, however, virtues as well as defects may stand in the way of success. Nor are the obstacles all non-intellectual: there is evidence that intellectual ability itself may constitute a handicap:

> The members of the gifted group whose IQ's are in the neighborhood of 170, 180, or 190 tend to have considerably more difficulty in making social adjustments than do the more typical members of the gifted group (page 183).
>
> Unfortunately, there are a good many teachers who get a certain satisfaction out of humbling the pride of their brightest pupils. We have considerable reason to believe that even university teachers find it hard to deal justly with the fourteen-year-old college freshman (page 277).
>
> The greater the intellectual gifts of a given child the more difficult is the problem of making the most of these gifts (page 481).

The last statement might have been made stronger, for in some circumstances intellectual superiority may prevent not only maximum achievement but any considerable achievement at all. The gifted child is a stranger in a world which he never made and which, moreover, was not made for him. The schools are not adapted to his needs.

*That class differences in intelligence quotients are to be explained environmentally is strongly indicated, as Professor Muller has pointed out, by the fact that they are approximately proportional to environmental differences between classes."

His associates are either too old or too unintelligent. The fact that his mentality is different from that of most other people prevents a mutual understanding.

Facts like these lead the authors to say, "In some respects it is to be regretted that exceptionally superior intellectual endowment shows itself so early." But mental superiority encounters similar difficulties at all ages. Imagination, initiative, and intelligence are likely to interfere with the routine work which is the primary requisite in most positions; hence mediocre individuals are often preferred. For many other reasons also there is a tendency toward degradation of intellect[9,13,14] — a tendency that some people who call themselves eugenists apparently wish to perpetuate.

From the standpoint of eugenics the most important future activity of the gifted individuals is marriage. The twenty-eight who have already married have selected mates on the average less gifted than themselves. Regression toward mediocrity in marriage is a general phenomenon; moreover the individuals who married relatively early are perhaps less discriminating than those who are waiting. Nevertheless the authors (somewhat like fond parents) cannot help being disappointed and suggest that the regression might be counteracted by eugenic education. But the situation is controlled largely by social and economic forces; and while these remain as they are, eugenic education, however desirable in itself, would, by making the gifted individuals more discriminating, postpone their marriage and decrease the number of their offspring.

For reasons already stated, this review has dealt largely with the limitations of the work. Many of these, as I have said, are recognized by the authors, and some will disappear as the experiment continues. It is to be hoped that the work will be carried to its completion and that it will inspire further inquiries of the same kind.

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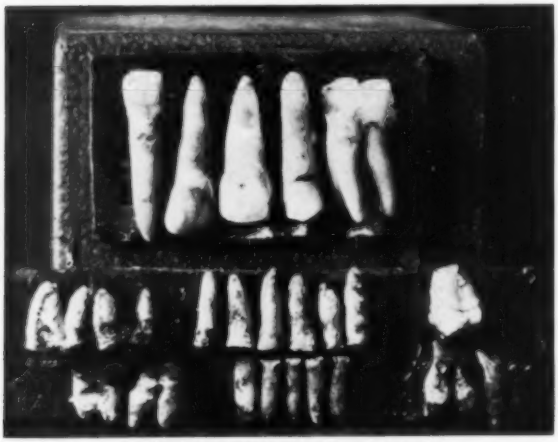
ABSENCE OF TOOTH ENAMEL

A Dominant Hereditary Anomaly in Man

FRANK H. CLARK and CECILE S. CLARK
Bussey Institution, Harvard University



TEETH WITHOUT ENAMEL

Figure 1

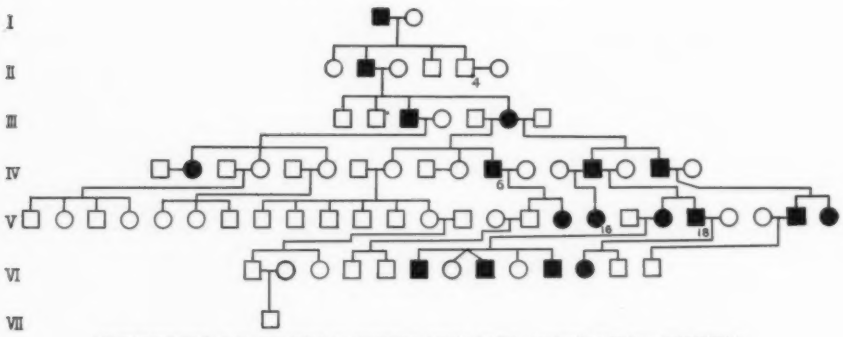
Above are shown normal teeth, with the covering of enamel which protects the softer interior from wear and bacteria. Below is shown a set of teeth lacking enamel, an inherited characteristic found in two New England families. Some of the teeth show traces of an enamel covering, but it is of poor quality and very brittle. The set of defective teeth shown here were extracted from the jaws of a man only twenty years old. (The tooth at the extreme right probably does not belong with the set of "no-enamel" teeth.) A cast of the jaws of this man is shown in Figure 5. Even at the early age at which the teeth were removed they had been worn even with the gums. This unusual condition is undoubtedly hereditary, having been traced for six generations.

SEVERAL hereditary tooth defects in man have been reported. Perhaps the most interesting case is that reported in this JOURNAL by Thadani[6], concerning a family living in India. Affected individuals of this group lack teeth and hair and are also very susceptible to heat. The abnormality is due, apparently, to a recessive sex-linked gene, since the daughters of affected fathers pass the defect on to half their sons. Roberts[4] has described a similar defect occurring in this country, and finds that it is inherited in the same way, as a recessive sex-linked character. People with this defect suffer from the heat because of absence or reduction in number of the sweat glands.

Ovazza[3] described a family in which the absence of all the incisor teeth was inherited as a simple Mendelian dominant.

Beade[1] reported a dental anomaly which, likewise, is inherited as a single factor dominant. The expression of the anomaly, however, differed greatly. Varying numbers of teeth were sporadically absent from either the deciduous or permanent set, and there were also irregularities in the age at which eruption of teeth took place.

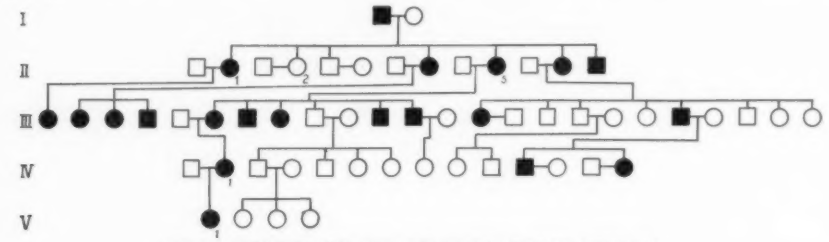
Huskins[2] described a dental abnormality consisting of the absence of the



PEDIGREE OF FAMILY WITH ENAMEL-DEFICIENT TEETH

Figure 2

It is evident from these pedigrees that the character is a typical dominant without sex-linkage. In the two families more than half of the children of affected individuals show defective teeth but the deviation is less than might be expected on a basis of chance.



FIVE GENERATIONS OF DEFECTIVE TEETH

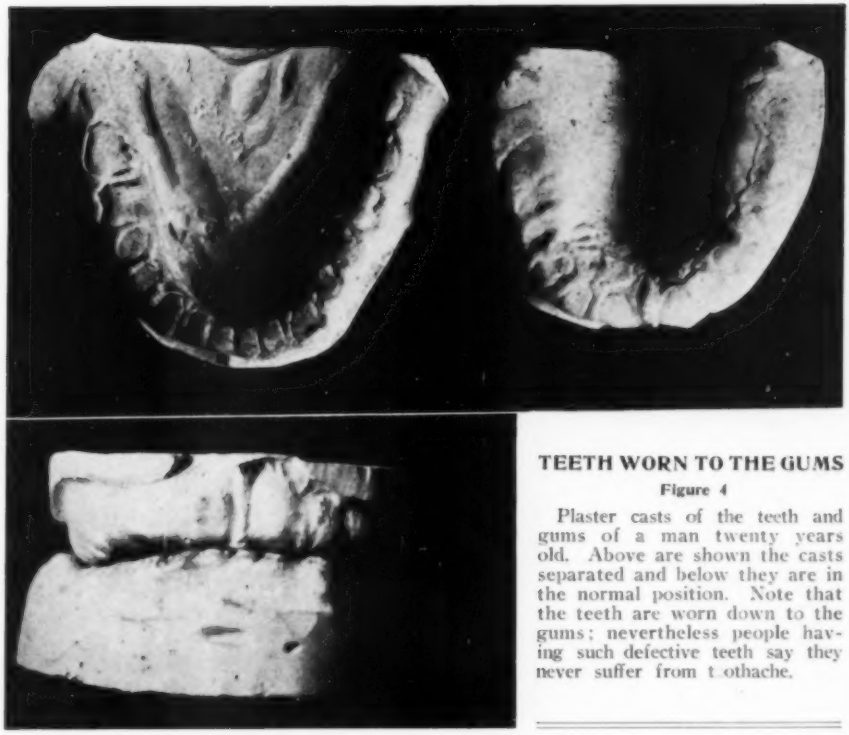
Figure 3

These two families are undoubtedly related, since the family name applied to the tooth defect was the same in both of them. It is believed that an ancestor bearing this defect came over on the Mayflower but documentary evidence of this is lacking.

two center incisors of both upper and lower jaws from both sets of teeth. In general, it behaved as a sex-linked recessive, being transmitted from an affected male to half his daughter's sons. In one individual, it behaved as a dominant, since the daughter of an affected male had it, while in another case it behaved as a dominant up to the age of 13.

Schultz[5] finds that a tendency to eliminate the upper lateral incisors, including the complete congenital lack of these teeth, is fairly common in the higher races of man. He shows, by various pedigrees, that this tendency is inherited in different ways in different families.

The tooth defect which we shall describe affects all the teeth of both the deciduous and permanent sets. The teeth lack enamel, are brown in color, and are only about one-half to two-thirds normal size. We were unable to obtain any of these teeth for a histological study, but through the kindness of Dr. Asaph Walker, dentist, in Bridgton, Maine, we were able to examine a nearly complete set of these teeth and also plaster casts of the jaws. The teeth which are shown in Figure 1 belonged to a man about 20 years old (Fig. 2, *V-18*). Above them in the figure are shown some normal teeth for comparison. The molar tooth shown at the extreme right of the mid-



TEETH WORN TO THE GUMS

Figure 4

Plaster casts of the teeth and gums of a man twenty years old. Above are shown the casts separated and below they are in the normal position. Note that the teeth are worn down to the gums; nevertheless people having such defective teeth say they never suffer from toothache.

dle row probably does not belong with this set of defective teeth. This particular set of teeth shows traces of enamel, but when enamel is present, it is brittle and of inferior quality. The roots are short and thick. It is evident that these teeth are much smaller than normal teeth, even though the crowns have, in most cases, been worn off. An X-ray photograph of two of the incisor teeth of this set is shown in Figure 5*D*. It is evident that a central pulp area is present. Pulp in the normal tooth is made up mostly of connective tissue infiltrated with blood vessels and nerves. One can scarcely conceive of the pulp and other parts of a tooth being formed without nerve connections. People possessing this defect claim that they never have the toothache, but in most cases they get rid of these teeth early in life. The teeth, because of their softness, wear down very quickly and, as they wear down, the central pulp area becomes filled with dentine. This occurs in the normal tooth but is a much slower process and rarely progresses so far. A clearer idea of what happens in the case of these defective teeth can be obtained by comparing Fig. 1 and Fig. 5*D* with Figure 5 *A*, *B*, and *C*. These latter figures are X-ray photographs of various parts of the lower jaw of a seven-year-old girl (Fig. 2, *V-16*) possessing this tooth defect. We are indebted to Dr. Noble of Bridgton, Maine, for the X-ray photographs and for information relative to them.

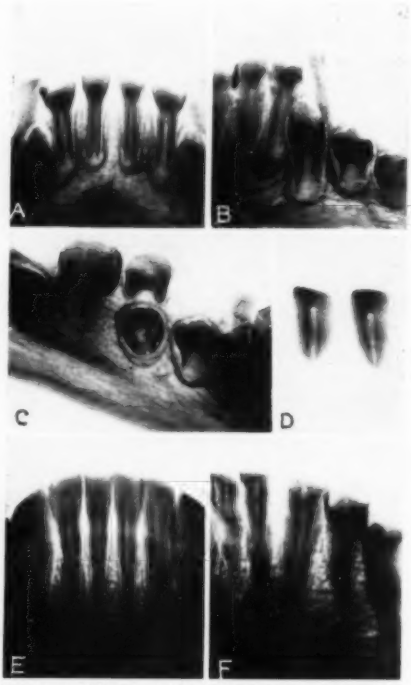
Figure 5*A* shows the four permanent front incisor teeth of the lower jaw. They extend well above the gum, possess crowns, and have central pulp areas. Undoubtedly if retained, the

crowns of these teeth will wear down until the teeth are nearly even with the gum, and the top part of the pulp cavity will become filled with dentine, as was the case with the teeth shown in Figure 5*D*. Figure 5*A* also shows the deciduous canine teeth being replaced by permanent teeth. Figure 5*B*, taken slightly to the side, shows two of the same incisor teeth and one of the canine, as well as two premolars. The canine and premolar teeth have definite cusps and central pulp areas. Figure 5*C* shows a permanent canine tooth about to break through the gum; also two premolars and the six year molar.

Plaster casts of the jaws of the man whose teeth have already been described may be seen in Figure 4. This figure shows that the teeth had worn down nearly even with the gums. Such individuals can masticate their food, but it is often a painful process because of the gum ridges extending up between the teeth. The jaws are well formed and normal. Figure 4 shows the appearance of the jaws and teeth when the mouth is closed. The jaws also appear normal in this position.

This particular tooth defect is reputed to have been possessed by an ancestor who came over on the *Mayflower*, but we have been unable to trace it back that far. We traced the anomaly through two families which are undoubtedly related, since the original family name applied to this peculiarity of the teeth is the same in both families. The two pedigrees are shown in Figures 2 and 3. There is one case of intermarriage between the two families in the second generation. Individual *II-4* in Figure 2 married *II-2* in Figure 3. Both of these persons had normal teeth, and no children resulted from this union.

From the pedigree charts it can be seen that the defect behaves as a typical dominant character and is not sex-linked. Individuals who possess the defect transmit it to approximately half their children, the other parent being normal. In these two families, children were born from 21 marriages of this type. The normal individuals do not transmit the defect, as is shown in the nine marriages of normals indi-



NO-ENAMEL AND NORMAL TEETH

Figure 5

X-ray views of the teeth lacking enamel compared with normal teeth of a young adult (*E*) and a habitual tobacco chewer about sixty years old (*F*). *A* and *B* show two views of the permanent incisor teeth of the lower jaw of a seven-year-old girl, *C* shows the deciduous canine teeth being replaced by permanent teeth. *D* shows two extracted incisor teeth. These should be compared with the normal teeth shown below (*E* and *F*). Note the extremely small size of the teeth, which have been worn down to the gums. Note also how the pulp area has become filled with dentine. The X-rayed tooth of the normal individual (*F*) shows the same condition to a lesser extent. Here after an average lifetime, the crown has been considerably worn down and the pulp area has become partially filled with dentine, but to a much less degree than in the defective teeth.

cated in Figures 2 and 3, which produced 27 normal children.

The affected individuals are accordingly regularly heterozygous dominants. What would be the character of a homozygous dominant is uncertain, as no matings between affected individuals seem to have occurred. Equal numbers of normal and affected offspring would be expected when individuals with the defect marry normals. The numbers actually reported are 23 normals to 37 abnormals. This is a deviation of 7 ± 4.35 from the expected 1:1 ratio. Although the number of individuals with this tooth defect is larger than expected, a deviation of this size is not statistically significant, and it is possible that affected individuals are more likely to be mentioned than normals in reporting family pedigrees, the interest of which centers in the abnormals.

In the process of interviewing numerous people in both families, several interesting discoveries were made. For instance, *II-5* in Figure 3 still has her lower set of defective teeth at the age of 84. This indicates that the teeth do not decay rapidly, although such a conclusion can scarcely be established from a single case.

Individual *IV-1* in Figure 3 had teeth which were intermediate in type. The teeth had enamel which was of poor texture and color. That she actually had this tooth defect is proved by the fact that she passed it on to her daughter *V-1*.

The most interesting case is that of *II-1* in Figure 3. This woman had only two deciduous teeth, both of which were abnormal. The permanent set of teeth, however, was complete and normal. The daughter of this woman had the usual defective teeth, proving that the mother carried the anomaly. Apparently the gene causing this defect, at least in certain cases, is influenced by modifying factors, constitutional or environmental in character.

Individual *IV-6* in Figure 2 had teeth all of which were said to be double as well as defective. The double condition of the teeth was not passed on to his offspring, though one of his two children had defective teeth. This shows that the double condition is independent of the defect under discussion and is either non-genetic or, if genetic in nature, then a recessive rather than a dominant character.

A tooth anomaly of this kind, while not so serious as many human abnormalities, is unfortunate. Nevertheless its social control is simple as compared with the control of a recessive character. Abstention from reproduction on the part of affected individuals would quickly bring its occurrence to an end, since unaffected individuals do not transmit the character, even though they have affected brothers and sisters.

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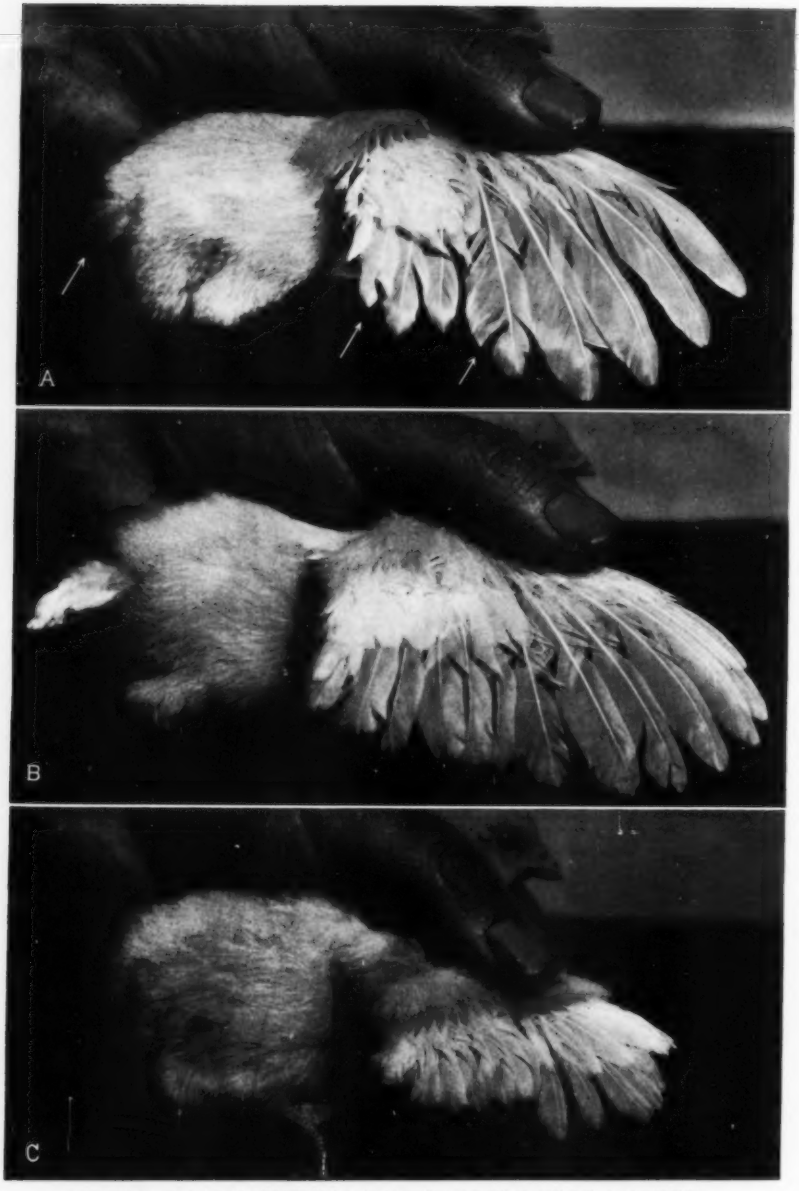
An Error in Twin Fingerprint Description

On page 408 (Figure 15) of the October Journal the lines directly above both halves of the illustration should read: "Twin A——Twin B——Sib".



TYPES OF FEATHERING IN THE TEN-DAY-OLD CHICK

Figure 6

(*A*) White Leghorn chick showing retarded feathering. It has normal primary flight feathers but only three well developed secondaries and no tail feathers. (*B*) Normal early feathering White Leghorn with well developed tail feathers and primaries and six well developed secondaries. (*C*) Normal late feathering White Plymouth Rock with no tail feathers and short primary and secondary flight feathers.

RETARDED FEATHERING IN THE FOWL

A New Factor Affecting Manner of Feathering

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SEREBROVSKY[1] first described a factor for rate of feathering in the domestic fowl and showed that the gene involved was carried by the sex chromosome. The expression of this factor for rate of feathering was more fully described later by the writer[2]. The allelomorphic pair involved was late feathering, characteristic of most of the heavier breeds, and early feathering found in the smaller Mediterranean breeds. Age at the appearance of tail feathers was used as a basis of classification of the phenotypes, those possessing tails at ten days of age being classed as early feathering and those lacking tails at this age as late feathering. The chicks also showed accompanying differences in the rate of growth of wing feathers. At ten days of age the early feathering chicks have primary wing feathers which are equal to or slightly beyond the length of the body, while these feathers of late feathering chicks are not much more than half the length of the body.

During the 1926 breeding season a few Single Comb White Leghorn chicks were observed which at ten days of age had primary wing feathers of the length characteristic of early feathering breeds but entirely lacking in development of tail feathers. The pedigrees showed that the chicks exhibiting unusual feathering came from a single mating. One male and three females of this type were reared to maturity and when mated together in 1927 produced offspring all of which showed the type of feathering characteristic of the parents.

A more careful examination of the chicks from this mating showed that there was not only a retardation of the development of the tail feathering but also of some of the secondary flight feathers. At two weeks of age the primaries and the first three or four secondaries appeared to be normal in length while the remaining secondaries were poorly developed. At this age a normal White Leghorn should have at least six well developed primary feathers and an equal number of secondaries. The primary feathers and full length secondaries were narrower and somewhat more ragged appearing than normal feathers. The ragged appearance was due to a lack of a firm web. The name "retarded" has been applied to this type of feathering. Retarded birds are entirely normal as adults, the first tail feathers appearing at about three weeks of age. At six weeks of age the retarded chick lacks the smooth appearance of normal White Leghorn chicks due to irregularities of body feathering.

During the earlier studies of retarded, classification was made at ten days of age recording the chicks with tails non-retarded and tailless ones as retarded. It was later found that the retarded feathering could be identified at hatching by examination of the secondary flight feathers. In the normal White Leghorn day-old chick, or any one carrying the sex-linked early feathering gene, there are at least six well defined primary flight feathers and an equal number of secondaries. At hatching these feathers are developed to considerable length and show very clearly on the under side of the wing. At this stage the flight feathers are still held within a sheath which gives them a needle-like appearance. The retarded chicks never have more than the first three secondaries well devel-

*Contribution No. 74 from the Department of Poultry Husbandry.

oped at hatching (counting outward from the axial feather) and it was found that segregates in the F_2 generation could be accurately classified by examination of the secondary flight feathers. Chicks classified at hatching and again at ten days of age checked perfectly so that for the later matings, chicks were classified as to feathering and killed for recording sex on the day of hatching. This character may thus be listed in the group of those that can be classified at hatching providing that the results are not complicated by the presence of sex-linked late feathering.

The various matings made for the study of the retarded factor are shown in Table I. All matings of retarded males by retarded females gave only retarded offspring. These matings included only purebred White Leghorns. The reciprocal matings of retarded and normal feathering were also of purebred White Leghorns. The normal feathering here was the sex-linked early feathering. The F_1 generation offspring were all normal feathered indicating that retarded is recessive to normal and non-sex-linked. If it had been sex-linked the daughters of the mating, retarded male by normal female, should have been of the retarded type of feathering.

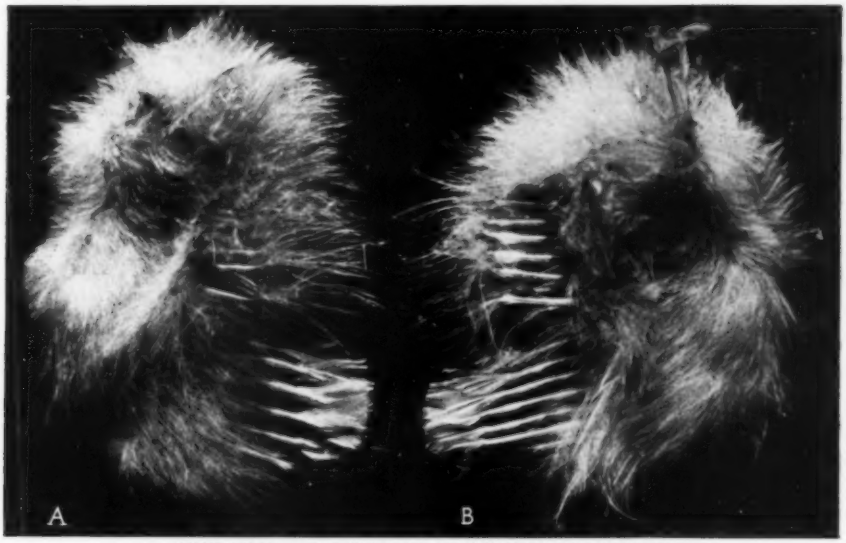
The back-cross results where heterozygous normal feathered females were mated to retarded males substantiated the suggestion that retarded is a simple recessive factor. The 112 retarded to 102 normal females and 122 retarded to 108 normal males approached very closely the expected 1:1 ratio. The single late feathering female was not to be expected and probably was an error in classification or in pedigree records. The back cross results included the mating of some crossbred birds but in no case was late feathering involved.

Interaction of "Retarded" and "Late-Feathering" Genes

Since it was known that late feathering constitutes a dominant sex-linked mutation of early feathering and retarded a recessive autosomal mutation, it was of interest to determine the reaction of late and retarded feathering. None of the previously mentioned matings involved the late factor. It should be recalled that early feathering chicks have long flight feathers and well developed tail feathers at ten days of age and late feathering ones have short flight feathers and no tail feathers at the same age. Retarded feathering chicks have long primary flight feathers and no tail feathers at ten days of age. Where only early feathering and retarded feathering were involved it was possible to distinguish at hatching the two types by the retarded development of some of the secondary flight feathers in the retarded type of feathering but since slow feathering chicks have very little development of any of the secondary flights, this was not pos-

Table I.—The Inheritance of Retarded Feathering.

Type of mating	Daughters			Sons		
	Retarded	Normal (early)	Late	Retarded	Normal (early)	Late
Retarded ♂ by retarded ♀	40	—	—	38	—	—
Retarded ♂ by normal (early) ♀	—	131	—	—	146	—
Normal (early) ♂ by retarded ♀	—	23	—	—	25	—
Retarded ♂ by F_1 ♀	112	102	1	122	108	—
Retarded ♂ by late feathering ♀	2	23	—	—	—	17
Male heterozygous for retarded and early feathering by retarded ♀	58	49	97	79	27	76



EFFECTS OF RATE-OF-FEATHERING GENES

Figure 7

Wings of day-old White Leghorn chicks showing distinguishing characteristics between the normal early and retarded types of feathering. Growth of primary flight feathers (lower side of figure) is very similar in the two types but the retarded type (*A*) shows only two well developed secondaries while the early feathering chick (*B*) has five conspicuous secondary flight feathers.

sible in the matings involving late feathering.

The last two matings listed in Table I were between retarded and late feathered individuals. The expected results would be those occurring where a sex-linked and autosomal pair of factors are involved. The first mating was that of a retarded White Leghorn male by late feathering Rhode Island Red females. This male would be homozygous for recessive early feathering and recessive retarded feathering while the females would be homozygous for dominant late feathering and dominant non-retarded. Since retarded feathering has the same influence on tail development as does late feathering and is expressed primarily by its influence on the development of some of the secondary flight feathers it might be carried by the late feathering stock without being evident. If the late feathering females did not carry the retarded factor the results from the cross of retarded male to late feathering females would be the same as if an ordinary early feathering male had been used. The retarded bird must carry early feathering and since retarded is recessive it would not express itself in the first generation of the above cross. The expected results would be late feathering males and early feathering females. The expected results were realized except that two retarded females appeared. The occurrence of these two females suggests that some of the mothers probably carried the retarded factor in a heterozygous condition.

We do not know how a bird should appear which is homozygous for retarded and for late feathering. Since the retarded factor inhibits the development of tail feathers and some of the secondary flight feathers, both of which are lacking in the early stages of development of the late feathering chicks, it seems probable that the presence of the retarded factor would in no way

affect the expression of the late feathering factor. If this assumption is correct we would expect in the last mating retarded, early, and late feathering in both sexes in the ratio 1:1:2. This ratio is approached in the females but in the males there is a considerable shortage in the early and late classes. It, therefore, appears that it is difficult to follow the segregation of retarded in the presence of late feathering.

Summary

Retarded is a simple autosomal recessive factor which modifies the expression of the ordinary early feathering. It is expressed in the day-old chick by retarding the development of the secondary flight feathers with the exception of the first three. In the ten-day-old chick it prevents the development of the tail as well as the above mentioned secondary flight feathers. Retarded is expressed only in the juvenile plumage since the factor cannot be identified in the adult. The presence of the sex-linked late feathering interferes with the identification of the retarded factor.

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Priority in Isolation of the Follicular Hormone

A Note on Professor F. A. E. Crew's Review of "Sex and Internal Secretions"*

IN Professor Crew's review of *Sex and Internal Secretions,* he has questioned the accuracy of my statements regarding the isolation of the first estrus producing compound. Actually I reported the first successful isolation of a crystalline product at the XIIIth International Physiological Congress before the section presided over by Professor E. Laqueur. Lantern slides of the crystals were exhibited and samples of the crystals were shown to several investigators. At that time Laqueur admitted that he had not obtained a crystalline preparation but claimed his preparation to be as potent as ours. Some months later he succeeded in obtaining a crystalline product.

If the reader is interested in ascertaining from the original literature whether Professor Crew was justified in his allegations of inaccuracy in my section of *Sex and Internal Secretions,* he may refer to the following sources of information: Doisy, Veler and Thayer, *Amer. J. Physiol.* 90, 329, 1929; Butenandt, *Die Naturwissenschaften* 17, 879, 1929; Marrian, *Physiological Review* 13, 191, 1933; Laqueur and co-authors, *Deut. Med. Wochnschr.* 56, 303, 1930; Girard, *Bull. Soc. Chem. Biol.* 15, 570, 1933.

E. A. Doisey.

Washington University, St. Louis.

*Journal of Heredity 24:250, 1933.

More Twin Psychology

PSYCHOLOGISCHE UNTERSUCHUNGEN AN ZWILLINGEN UND GESCHWISTERN UBER DIE VERERBUNG DER KOMBINATIONS-FAHIGKEIT, DER INTELLIGENZ, UND DER PHANTASIE, *by* Walter Kohn. Pp. 69. Leipzig: Akademische Verlagsgesellschaft, 1933. (Reprinted from *Archiv für die gesamte Psychologie,* Band 88.)

THIS is another attempt to evaluate, by means of the twin-method, the respective contributions of heredity and environment to the development of mental traits. 27 pairs of identical twins and 36 pairs of like-sexed non-identical twins, together with a num-

ber of sibs and unrelated controls, were given tests designed to ascertain intelligence, imaginative ability, and type of imagination. Unfortunately, most of the data are presented without distinguishing between the sibs and the unrelated controls.

Despite some methodological innovations, nothing new seems to emerge from this study, the results of which are quite in line with those of previous investigations. The psychologist might find some interest in the correlations shown between individual ratings on the various tests, though he might also find much to disapprove in the nature of certain of the tests themselves, which, to the non-psychologist reviewer, seem to demand undue subjective discrimination for their grading.

Kohn calculates from his data a numerical value for the part played by the environment in establishing differences in performance on each type of test; this procedure would tempt criticism except for the fact that the author himself, despite his extensive use of it, manages to express incidentally his realization of its lack of definite significance.

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Books Received

***BOOKS** are acknowledged in this column as received, and such acknowledgment must be regarded as sufficient return for the courtesy of the sender. As far as space permits, books that contain material of special interest to the reader of the* JOURNAL *will be reviewed in later numbers.*

A STUDY OF A COMMUNITY AND ITS GROUPS AND INSTITUTIONS CONCEIVED OF AS BEHAVIORS OF INDIVIDUALS. A psychological monograph. *By* RICHARD LOUIS SCHANCK, Assistant Professor of Social and Political Psychology in the School of Citizenship and Public Affairs, Syracuse University. Edited by Herbert S. Langfield, 135 Pages. Published by the Psychological Review Company, Princeton, N. J., 1932.

CHARLES DARWIN'S DIARY OF THE VOYAGE OF H. M. S. "BEAGLE," Edited from the MS *by* NORA BARLOW. Pages 451, illustrations, index, bibliography. Price, $6.50. The Macmillan Company, New York, 1933.

The voyage of the *Beagle*, in Darwin's own estimation the most important event in his life, did its part in spoiling a country parson and in giving the world thirty years later a new earth, in the *Origin of Species*. The complete text of the manuscript diary, here published for the first time, traces in intimate detail the changes in outlook wrought by the voyage. This, rather than any scientific contribution, is the outstanding feature of the book.

JOCASTA'S CRIME, *by* LORD RAGLAN. An anthropological study. 215 Pages. XXVI Chapters. Bibliography and index. Price $2.25, E. P. Dutton & Co., Inc., New York, 1933.

Speculations as to the whys and wherefores of the great variety of incest taboos found among humans—primitive and civilized.

LIFE IN THE MAKING, The Story of Human Procreation, *by* ALAN FRANK GUTMACHER, Associate in Obstetrics, Johns Hopkins University, with the assistance of Ellery Rand. September selection of the Scientific Book Club. 297 Pages, viii figures, index, and list of Supplementary Reading. Price $2.75. The Viking Press, New York.

Yet another addition to the five-foot-shelf on the so-called "Facts of Life."

DAS MENSCHLICHE AUGE UND SEINE ERBANLAGEN *by* P. J. WAARDENBURG, Augenarzt in Arnham. 631 pages, 8 farbigen tafeln und 197 textabbildungen, 20 Chapters, index, bibliographies at the end of each chapter. Price 30 gilders, Martinus Nijhoff, The Hague.

APPLIED EUGENICS *by* PAUL POPENOE, Secretary, the Human Betterment Foundation and Director of the Institute of Family Relations, Los Angeles, and Roswell Johnson, Professor in the University of Pittsburgh. Social Science Text-Books. edited by Richard T. Ely. Revised Edition, 429 Pages, index, glossary, bibliography, illustrations. Price $2.60, The Macmillan Company, New York, 1933.

A long-awaited second edition at last appears.

THE LONG ROAD FROM SAVAGERY TO CIVILIZATION, *by* FAY-COOPER COLE, Professor and Chairman, Department of Anthropology, University of Chicago. Pages 100. 5 Illustrations. Price $1.00. The William & Wilkins Company, Baltimore, 1933.

This book is one of the Century of Progress Series, a series of volumes by well-known scholars presenting the essential features of those fundamental sciences which are the foundation stones of modern industry. Other titles in the Century of Progress Series are: The Universe Unfolding, Evolution Yesterday and Today, Insects—Man's Chief Competitors, etc.

KUHN-ARCHIV, Arbeiten aus den Landwirtschaftlichen Instituten der Universitat. Band 33. Published by Paul Parey, Berlin, 1932. Pages 456, tables, and graphs.

PROCEEDINGS OF THE SIXTH INTERNATIONAL CONGRESS OF GENETICS, Ithaca, New York, 1932, vol. 1, Transactions and General addresses. Published at Menasha, Wisconsin by the Brooklyn Botanic Garden.

The Presidential Address to the Congress assumes a new interest since the man who gave it has been awarded the Nobel Prize.

MAN INTO WOMAN, Edited by Niels Hoyer, translated from the German by H. J. Stening with an introduction by Norman Haire, Ch.M., M.B. An authentic record of a change of sex. 288 pages, 18 illustrations, price $3.50. E. P. Dutton & Co., Inc., New York, 1933.

Authentic, perhaps, but apparently done in a way to reduce its scientific value to a minimum.

SEX IN THE PLANT WORLD *by* WILFRED W. ROBBINS, Ph.D., Professor of Botany in the College of Agriculture of the University of California and Helen Pearson, Ph.D., Research Assistant in Viticulture in the College of Agriculture of the University of California. Pages 193, index, illustrations. Price $2.00. D. Appleton-Century Company, New York, 1933.

The "facts of life" in a sphere in which the change from man to woman is an everyday occurrence, and in which hermaphrodites are constantly to be seen outside of medical journals.

WHAT WE ARE AND WHY *by* LAURRENCE H. MAYERS, M. D., Professor of Medical Research in the Medical School of Northwestern University, in collaboration with Arthur D. Welton. A study with illustrations, of the relation of the endocrine glands to human conduct and dispositional traits, with special reference to the influence of gland derangements on behavior. Illustration, glossary, 340 pages. Price $3.00. Sears Publishing Company, Inc., New York, 1933.

LIMITATIONS OF SCIENCE *by* J. W. N. SULLIVAN. Pages 307, index. The Viking Press, New York, 1933.

HEREDITY AND THE SOCIAL PROBLEM GROUP *by* E. J. LIDBETTER, volume I with an introduction by Leonard Darwin. Pages 160 with 26 pedigrees. Price 21s. Edward Arnold & Co., London, 1933.

Enough pedigrees of defectiveness and deficiency to convince even G. K. Chesterton there may be something in heredity!

BORN THAT WAY *by* JOHNSON O'CONNOR with an introduction by F. P. Cox. A report of several years' experimenting with selective tests, practically applied in industry, in various localities, to various groups, for various occupations. Pages 326, appendices, index, illustrations. Price $6.00. Williams & Wilkins Company, Baltimore. 1933.

The mental and aptitude tests brought up to date by an authority in that field who is convinced there is quite a lot to this heredity business.

THE ORIGIN OF THE MARSH SEEDLESS GRAPEFRUIT

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THE Marsh (Seedless) grapefruit has become in the last decade the dominant commercial variety for planting in Florida, Texas and the Southwest. Likewise in foreign countries, namely, South Africa, Palestine, Australia and South America, the Marsh is the variety commanding the most attention. Its seedless character is probably chiefly responsible for this development, but other factors contribute to its trade popularity. Its relatively small size as compared with the older seedy varieties, and its good holding quality are both strongly in its favor. With the greatly increased sales through the cheaper channels of trade, notably in the chain stores, the medium and small sizes, formerly sold at a discount, are now most in demand and command a premium.

The variety is known to have originated near Lakeland, Florida, and was introduced by C. M. Marsh, a nurseryman of Lakeland, about 1895. Hume[1] in his standard work on Citrus states that the "original tree was a seedling."

In 1927 the *Los Angeles Times*[6] printed an account of the supposed origin of the variety. This account was given by Mr. E. H. Tison, a California resident, but formerly a pioneer Citrus grower and nurseryman of Lakeland, Florida. In his account, which was quite lengthy and made convincing by the introduction of considerable circumstantial detail, he claimed that the original tree producing seedless fruits had its origin as a broken off root sprout from an ordinary seedling grapefruit which produced only seedy fruits. He stated that this occurred in the grove of John Hancock, who showed him this strange tree (producing fruit at the age of three years) and allowed him to take budwood and start the propagation of the new variety; and that later he sold his nursery to Mr. Marsh who gave his name to the variety. This was said to have happened about 1886, before the so-called "Great Freeze" of 1894-5, which killed the original tree.

The Tison account was copied by such Citrus publications as the *California Citrograph* and the *Florida Grower*, and was in a fair way to become accepted as an established fact, placing this important variety in the category of bud sports and giving it unusual interest both from a scientific and economic viewpoint.

The writer recently had the opportunity to check up on this reported manner of origin, visiting the Hancock grove where the original tree stood and interviewing several members of the Hancock family and other local residents who from their childhood knew the tree.

The location given by Mr. Tison was "about 20 miles west of Lakeland, in Polk County." The Hancock property is about 12 miles north of Lakeland near an old settlement known as Socrum. The original tree grew in the grove of William Hancock, not John Hancock, who was a son of William Hancock. The two places, about a mile apart, are still occupied by members of the Hancock family.

Instead of a three-year-old sprout, every one who knew the original tree agreed that it was a large old seedling thirty or more years old at the time the buds were first taken from it for propagation. Inquiry among local residents as well as members of the Hancock family developed the fact that the tree bearing seedless fruits was one of three seedling grapefruit trees planted and

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cared for by a Mrs. Rushing from whom William Hancock bought the place in 1862. The tree stood at least 40 feet from either of the other two grapefruit trees and had a slightly different habit of growth. It had a flattened top and was allowed to branch fairly low, giving it an umbrella shape. The description of fruit characters given by those who were familiar with the original tree agrees exactly with the known character of the Marsh fruit today. The tree was in a decadent condition when the freeze occurred in the winter of 1894-95 and succumbed to cold injury.

Whether Mr. Tison was the first to take buds and start propagation of the seedless variety is uncertain, but it is known that others in the Lakeland region secured buds and started propagating the variety about the same time. The late Minor Stephens of Lakeland and Mr. Carson of Frostproof are known to have taken buds from the original Hancock tree but appear to have done so mainly for their own use and not for nursery purposes. Mr. N. O. Cressup of Lakeland, a pioneer nurseryman, however, propagated the seedless grapefruit in his nursery and like Mr. Tison sold his stock of buds to C. M. Marsh who evidently appreciated the potential value of the new variety more than his contemporaries. It is evident therefore that several parties initiated the propagation of the variety substantially at the same time. Mr. Marsh in addition to buying out the nursery buds of Tison and of Cressup, took budwood in considerable quantity from the original Hancock tree.

It is somewhat difficult to explain the circumstantial account of the origin of the Marsh grapefruit from a broken root sprout. It occurred to the writer that a root sprout from the original tree might have been transplanted by John Hancock from his father's place and that Mr. Tison had seen it growing there and had secured budwood from this young tree. Both of the brothers of John Hancock now living are positive, however, that no such tree ever existed on their brother's place. If they are correct in their recollection it is probable that the Tison account arose through the unconscious transfer of attributes belonging to some other tree which did arise from a root sprout, this mental confusion occuring after the lapse of a long term of years. There are known instances of thrifty citrus trees being produced from root sprouts, but they are usually identical with the original tree, or with its root system, if a budded tree.

Mr. Cressup gave the writer an account of one of his first budded plants of the seedless variety which in a vague way suggests the Tison account. He pulled up and cut off a crown root from a lime tree near his house and inserted a bud of the seedless grapefruit in this root. After this bud grew out and matured its first growth the root was again put back under ground so that the bud at the point of union would be protected against cold. It had, of course, all the appearance of a root sprout. The lime tree which furnished the stock was cut off to give room for the new bud. This bud grew rapidly and fruited in its third year. The tree so budded survived several freezes and was only recently removed in opening up a new city street. The place and circumstances differ materially from the Tison account, but there is enough similarity to suggest a possible basis for the root sprout theory of origin.

Mr. Cressup now lives in Lakeland on the very site of the original Marsh nursery. The Tison nursery immediately adjoined it on the south, both being on the shores of Lake Mirror. The writer found several fine old trees of the Marsh grapefruit now growing as dooryard trees in this neighborhood, probably the oldest trees of the variety anywhere in existence.

Other Seedless Forms

At least three other seedling grapefruit trees are known to the writer in Florida which produce practically seedless fruits. One of these grew in the U. S. Citrus Hybrid Test Grove at Little River, Florida, a five-acre grove

planted out about 1890 to Citrus hybrids created by Walter T. Swingle and Herbert J. Webber. The tree which gave rise to seedless fruit was planted as a supposed hybrid of grapefruit and tangerine—i. e., a tangelo—but produced fruit like the female parent except for the absence or scarcity of seeds. There is good reason to believe that budwood from this tree gave rise to the so-called Davis (Seedless) variety, the parent tree of which has never been definitely identified. Buds of the Davis variety and buds from the false bybrid tree in the Government Grove grown side by side on the same stock are identical in fruit and vegetative characters, both differing from the Marsh in shape, flavor and time of maturity of the fruit. In both cases the fruits may be entirely seedless or may have from one to five seeds. This authentic origination of a seedless grapefruit presumably as a result of cross pollination (tangerine pollen being used on the grapefruit blossom) suggests that the original Marsh seedless might have originated in a like manner, through insect transfer of foreign pollen to the bloom of an ordinary grapefruit.*

Another seedling grapefruit tree at Winter Haven, Florida (locally known as the Dorothy Seedless) produces seedless fruit. It may be a seedling of the Marsh variety, as it resembles the latter in many ways.

A third seedless grapefruit, locally known as the Perfection, was recently found by the writer at Oneco, Florida. The original seedling tree is one of an old seedling planting, all the other trees of which produce only seedy fruits. This seedless strain has not been sufficiently tested as yet to develop its differences from the other known seedless varieties but there is every indication that this represents still another independent origin of a seedless grapefruit from an ordinary seedy strain.

It is of some interest that a mutation of the Marsh gave rise about 20 years ago to a pink-fleshed strain of grapefruit which has been named the Thompson, after the owner of the grove in which the bud mutation was first discovered.[3] This grove is located at Oneco, Florida, immediately adjoining the nursery of Reasoner Brothers, who introduced the pink grapefruit into culture. This mutation is growing in popularity and bids fair to rival the parent variety as a favorite for commercial planting.

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5. ————. Recapitulation of Seedling Characters by Nucellar Buds Developing in the Embryo Sac of Citrus. *Proc. Sixth International Cong. Genetics,* 196-197, 1932.

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*With such Citrus seedlings, even when originating from the seed of cross-pollinated fruits, there is always uncertainty as to their being derived from the true embryo of the seed unless the seedling gives unmistakable evidence of being a true hybrid. This is due to the fact that the seeds of Citrus usually produce multiple sprouts, the extra sprouts arising from apogamic embryos or "nucellar buds."[2,4] These nucellar buds, arising as they do from the tissue of the mother plant, reproduce the variety without change except that there is often observed an increase vegetative vigor. The rejuvenation of a senescent Citrus variety made possible through nucellar bud propagation has recently been pointed out by Swingle and given the name "neophyosis."[5]

In the case of a seedless grapefruit originating from the seed of a seedy strain, the presumption would be fairly strong that the seedling in question arose from a true embryo rather than from one of the nucellar buds, since the latter, as far as known, reproduce the mother variety in all essential characteristics.

INHERITANCE OF FOOT LENGTH

In a Mouse Species Cross

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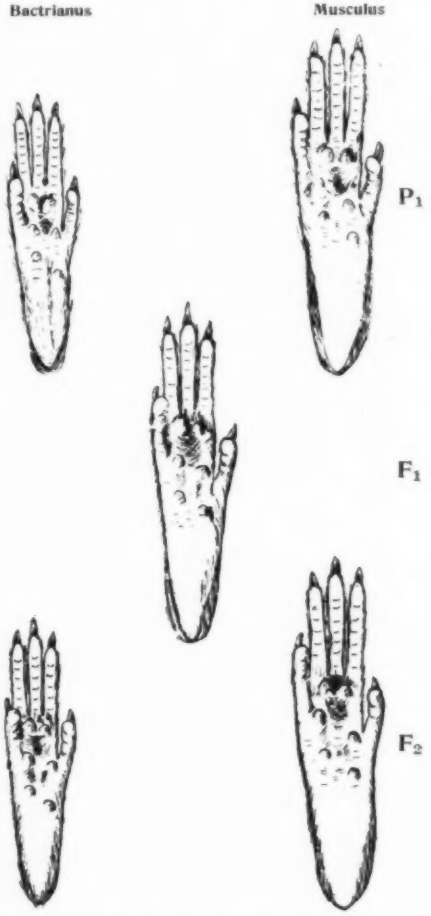
THE use of hind foot length as a quantitative character offers several advantages in a study of size inheritance in the mouse. Foot length, unlike the most commonly employed measure of size, weight, is unaffected by transient conditions such as amount of food ingested, degree of obesity, etc. It has the further advantage of attaining maximum size at an early age—approximately one month. Moreover, its measurement does not necessitate the death of the animal. Since this dimension differs markedly in the two species, *Mus bactrianus*, and *Mus musculus*, their hybrids offer excellent material for a study of its inheritance.

The strain of *Mus bactrianus* is derived from animals captured near Peiping, China and brought to the United States in 1926. They are small, relatively short-tailed murids with an average weight but little more than half that of the mice in the strain of *Mus musculus* with which they were crossed. *Bactrianus* differs from *musculus* not only in size but in certain morphological characters as well. The smaller species, for example, possesses approximately five fewer caudal vertebrae than its larger congener. In color *bactrianus* is intense black agouti (*DBA*^{w}), as contrasted with brown non-agouti *musculus* (*dba*) of the Little dilute brown strain. Although the two forms are specifically distinct, they cross readily, producing hybrids of which both sexes are fertile.

The hind foot was measured on animals either anaesthetized with ether or freshly killed, the procedure being the same in both cases. The right foot was placed firmly on paper, sole down, while, with a sharp pencil, a mark was



RELATIVE FOOT-LENGTHS

Figure 8

This drawing shows the relative lengths of the means of the hind feet of the two parent species and of the F_1 hybrids. The extreme variations observed in the F_2 are shown in the lower line.

made at the heel and at the distal end of the third digit including the claw. The distance between the marks was measured with vernier calipers registering in tenths of a millimeter. In the hybrid generations, only females were included, the males having been killed at weaning. In the two parental species the sexes are combined although males are given in terms of their female equivalents. These were obtained by dividing the mean female by the mean male length in each species and multiplying the individual males of that species by the quotient obtained.

Table I* presents the mean hind foot length in the several groups. *Bactrianus* ranges from 15.4 to 18.0 mm. with a mean of 16.52 ± .07 while *musculus* varies from 20.0 to 21.3 mm. with a mean of 20.56 ± .06. The F_1 hybrids are intermediate, although near to *musculus*, the mean being 19.78 ± .04 mm. with extremes of 18.8 and 20.4. The back-crosses to *musculus* have a mean foot length of 19.70 ± .04 mm., very close to that of the F_1's, but range from 18.3 to 20.9 mm. They are, however, more variable since the standard deviation is .522 as compared with .398 in the F_1 generation. The F_2 mice with a mean of 18.80 ± .04 mm. are much more variable than the F_1's, for they range from 16.8 to 20.6 mm. and have a standard deviation of .663.

The data given present a typical picture of multiple factors with heterosis manifested in the F_1 hybrids. The F_2 mean sinks back to an almost strictly intermediate position with that of the back-cross between it and the mean of the large parent race. The back-cross generation is somewhat more variable than the F_1 while the F_2 greatly exceeds either in variability.

Since *musculus* with greater foot length possesses chromosomes with the recessive genes for dilution, brown and non-agouti, while small *bactrianus* has their three dominant allelomorphs, an opportunity is given for the detection of linkage between size and color factors in the back-cross and F_2 generations. In the back-cross, dominant and recessive members of each of the factor pairs are expected in equal numbers while in the F_2 there should be three times as many dominants as recessives. Thus, if any one of the three "marked" *musculus* chromosomes also carries genes making for greater foot length, back-cross and F_2 mice exhibiting the corresponding recessive color should tend to have longer feet than those animals with the dominant allelomorph. To ascertain this, all intense animals in each generation were compared with all dilute, black with

*TABLE I.—Foot Length in Mouse Species and Hybrids

	No.	Mean (mm.)	δ
Bactrianus	33	16.52±.07	.557
Musculus	19	20.56±.06	.356
F_1	39	19.78±.04	.398
Back-cross	75	19.70±.04	.522
F_2	157	18.80±.04	.663

TABLE II.—Comparison of Foot Length in Recessives and Dominants

	Color	No.	Mean (mm.)	Difference	Difference / P.E.
Back-cross					
	Dilute (*d*)	40	19.76±.05		
	Intense (*D*)	35	19.63±.06	.13±.08	1.6
	Brown (*b*)	32	19.96±.05		
	Black (*B*)	43	19.51±.05	.45±.07	6.4
	Non-agouti (*a*)	39	19.63±.06		
	Agouti (A^w)	36	19.78±.06	—.15±.08	—1.9
F_2					
	Dilute (*d*)	29	18.71±.09		
	Intense (*D*)	128	18.82±.04	—.11±.10	—1.1
	Brown (*b*)	41	18.97±.07		
	Black (*B*)	116	18.74±.04	.23±.08	2.9
	Non-agouti (*a*)	40	18.79±.07		
	Agouti (A^w)	117	18.81±.04	—.02±.08	—0.3

brown, and agouti with non-agouti with the results listed in Table II.

From this table it is obvious that the back-cross mice with the gene for brown have, in general, significantly longer feet than those with the dominant allelomorph, black, while in neither of the other factor pairs does a significant difference appear. In the F_2 generation the same tendency is evident although less strongly marked. In an earlier paper the writer[1] reported a similar association in heredity between brown coat color and size in several quantitative characters, including femur and tibia length, but not in others such as cranial dimensions, so it seems probable that at least some of the size factors postulated on the chromosome with the gene for brown are what Wright[2] designates "group" factors, affecting the bones of the hind limb as a whole, rather than separate special factors influencing femur, tibia, and metatarsals, phalanges and other bones of the foot.

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Radium and Organisms

BIOLOGIE DES RADIUMS UND DER RADIOAKTIVEN ELEMENTE. *Vol. 1,* Biologie des Radiums and Uraniums (Biology of radium and uranium). *By* J. Stoklasa and J. Penkava, XV, 958 pp., 152 text figures, 1 color plate. Price 74 marks. Paul Parey, Berlin, 1932.

THE work by Stoklasa and Penkava, the first volume of which has been published recently, proposes to cover all that is known concerning the physiological effects of radium and radioactive elements on living organisms. The first volume deals only with radium and uranium. The opening chapters of the book review the facts relating to the radioactivity of the atmosphere (including the air of the soil), of the lithosphere, and of the hydrosphere. Next is discussed how the radiation enters plant and animal organisms. The remaining chapters give a detailed account of such questions as the influence of radioactivity upon the metabolism of bacteria, the germination of seeds, the growth and metabolism of plants, the chemistry of sugar catabolism in plant and animal cells, the anaerobic respiration of plants, cellular respiration, the mechanism of carbon dioxide assimilation in plant cells with and without chlorophyll, the utilization of direct light for the processes of photosynthesis, effects upon growth and cell multiplication, and the effects of radioactivity upon metabolic and catabolic processes in animals. All these and similar questions are discussed in great detail. Much (perhaps too much) space has been allotted to Stoklasa's own work. There is an extensive bibliography at the end of each chapter.

This book does not contain anything that has a direct bearing on genetics, but many of the problems discussed in it should be of great interest to those who are using radium in connection with genetic problems. It is announced that the second volume will contain a discussion of the application of radium in plant and animal breeding and in therapeutics.

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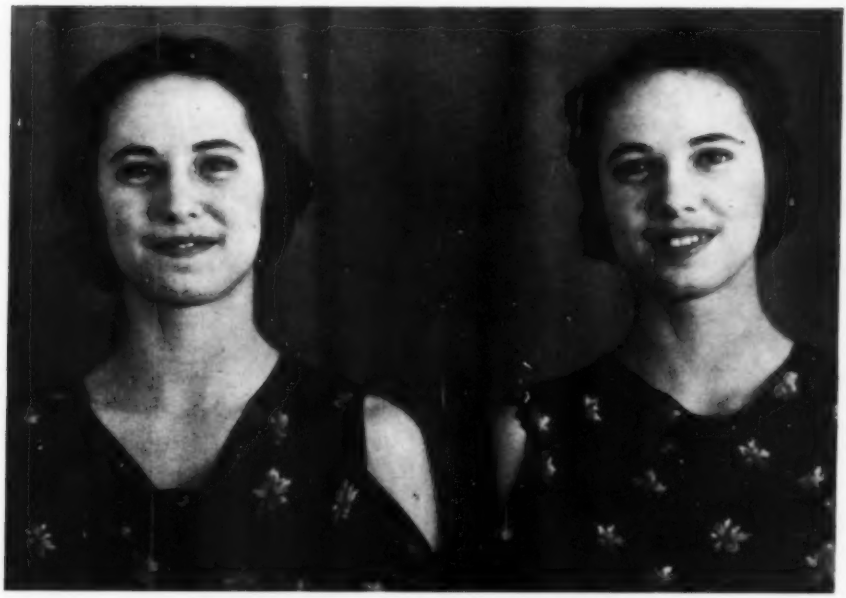
GENETIC STUDIES OF MONOZYGOTIC TWINS

III. Mirror-Imaging*

D. Cecil Rife



MIRROR IMAGING IN EYE DOMINANCE

Figure 9

These twins are strikingly similar in mental and physical traits. Except in eye dominance they show no symmetry reversal. Eye dominance was the characteristic studied which most frequently showed a mirror-image relation. This is probably to be accounted for by the fact that the development of the eye is initiated at an early stage of embryonic development.

MIRROR-IMAGING in regard to direction of head-hair whorl and handedness is among the most interesting phenomena encountered in studies of monozygotic twins. In our investigations of twenty pairs of monozygotic twins, we have determined, whenever possible, the direction of head-hair whorl, handedness in both unimanual and bimanual operations, and eye dominance.

In Table I we have used the symbols *cl* to represent a clockwise, and *cc* to represent a counter-clockwise direction of head-hair whorl. A double crown would be represented by *cc cc, cc cl,* or *cl cl,* according to the individual.

The observations of J. M. Rife[6], later confirmed by Downey's[2] statistical survey of about fifteen hundred individuals, show impressively the value of studying both unimanual and bimanual performances, when investigating handedness. According to this classification, a person's dextrality type is shown by his handedness in respect to each of the following kinds of performances: Group 1—unimanual op-

*Prepared at the Genetics Laboratories of Ohio State University, under the supervision of Prof. L. H. Snyder.

erations; Group 2—bimanual operations in the following order: bat, golf club and ax; Group 3—spade, pitchfork, shovel and broom. Individuals who are right-handed in respect to all three types of performances are classified as *RRR*, if righthanded for Groups 1 and 2, and left-handed for Group 3, they are *RRL*, and if right-handed for unimanual operations and left-handed for all bimanual operations they are classed as *RLL*. Similarly, we find corresponding types of left-handed individuals: thus any individual may be classified under one of the following types of dextrality:

Right-handed	Left-handed
RRR	LLL
RRL	LLR
RLL	LRR
RLR	LRL

Most right-handed individuals are *RRL*. *RLR* and *LRL* individuals are extremely rare. In Table I, we have used the above system in classification of handedness.

The Parson Manoptoscope was used in the determination of eye dominance or eye preference (the eye used for sighting, looking through a microscope, etc., is not necessarily the stronger). In Table I, *R* represents right-eye dominance, *L* left-eye dominance, *RL* and *LR* no distinct dominance.

Symmetry reversal was most often encountered in eye dominance, fifteen out of twenty cases showing partial or complete reversal. Eight out of twenty cases showed partial or complete reversal in handedness, while six out of fifteen showed reversal in the direction of head-hair whorl. (We could not determine the direction with certainty in five cases.) In all cases showing any reversal in handedness, reversal of eye dominance is also shown. Reversal in the direction of hair whorl occurs with or without reversal in both eye dominance and handedness.

Bernstein[1] has presented evidence which indicates that ordinarily the direction of the occipital hair whorl is determined by a pair of unit factors, a clockwise direction being dominant to a counter-clockwise direction. Left-handedness occurs much more frequently in some family strains than in others. There are numerous records of naturally left-handed individuals who have become stammerers when forced to learn to write with their right hand. These facts indicate that handedness is at least partially determined by heredity, although the extent and manner of its transmission is unknown. How can monozygotic twins, having the same genetic makeup, show intra-pair differ-

TABLE I.—Classification of Handedness

			Handedness	Eye dominance	Hair-whorl
Case I	Twin	A	RLL	L	?
	"	B	RLL	R	?
Case II	"	A	RRL	L	cl
	"	B	RRL	R	cl
Case III	"	A	RRR	R	cc
	"	B	RRR	R	cc
Case IV	"	A	RRL	R	cl
	"	B	RRL	R	cc
Case V	"	A	RRL	R	cl
	"	B	RRL	R	cl
Case VI	"	A	RRR	R	cl
	"	B	RRR	L	cl
Case VII	"	A	RRL	R	cc
	"	B	RRL	R	cc
Case VIII	"	A	RRL	L	cc
	"	B	RRL	R	cl
Case IX	"	A	RRR	L	cc
	"	B	RRL	R	cl
Case X	"	A	RRL	R	cc
	"	B	RRR	L	cl
Case XI	"	A	RRL	RL	cl
	"	B	RLL	RL	cl
Case XII	"	A	RLL	L	?
	"	B	RLL	R	?
Case XIII	"	A	RRR	R	cl
	"	B	RRL	L	cc
Case XIV	"	A	RRL	L	cl cl
	"	B	RRL	R	cl cl
Case XV	"	A	RRL	L	?
	"	B	RRR	RL	?
Case XVI	"	A	LRL	L	?
	"	B	RLL	R	?
Case XVII	"	A	RLL	L	?
	"	B	RRL	R	?
Case XVIII	"	A	RRL	L	cl
	"	B	RRL	R	cl
Case XIX	"	A	RRL	L	cc
	"	B	RRL	R	cl
Case XX	"	A	RLL	R	cc
	"	B	LRR	LR	cc

HANDEDNESS REVERSED

Figure 10

These girls are complete mirror-images in regard to handedness. Each has a counter-clockwise hair whorl, and they show partial reversal in eye dominance. Mirror-imaging appeared to have little relation to the degree of resemblance in the twins.

ences in respect to traits ordinarily determined by heredity?

Diver[3], in an investigation of the inheritance of inverse symmetry in the snail (*Linnea peregra*), made the following observations, which may have some bearing on the principles involved in mirror imaging in monozygotic twins.

> The final symmetry of an individual snail is apparently determined by the combined action of the chromosomes involved and the germinal structure, which action has a delayed effect. To be specific: factors determining and influencing the final result are resident in the chromosomes; these factors are distributed during gametogenesis in the now generally accepted manner; the determination of the final result is brought about by the combined action of the pair or pairs of chromosomes involved, and the germinal structure of the cell as a whole; the effect of the combined action is to delay the appearance of the nuclear pattern until the next generation. . . . . The determination of an individual rests upon the interaction of the parental nuclear forces (which segregate in a normal manner), and the existing modification imposed on the germinal structure of the parent by the nuclear forces of the preceding generation.

It is a well established fact that the sex of an individual is determined, normally, at the time of fertilization; it has also been shown, especially with certain plants, that by changing certain environmental conditions, the normal expression of sex may be changed, so that either an unusually large propor-

tion of males or of females may develop. Sex is quantitative, and the type expressed seems probably due to genes affecting metabolic rate, most of which are located in the X-chromosome. Outside factors affecting metabolic rate might possibly change the normal sex expression. Analogous processes may cause the mirror-imaging sometimes found in monozygotic twins. The environment of monozygotic twins is different from that of other individuals after cleavage of the embryo occurs, and may, like the germinal structure of the parent in *Linnea peregra*, modify the expression of certain genetic traits. Traits which show mirror-imagaing, although hereditary, may, like sex, be the end products of a series of processes controlled by the types of genes present, rather than being due to direct genic action; thus unusual conditions may alter the expression of such traits. Newman[4] states:

> The difference between the two sides may be reduced to terms of rate of fundamental vital activity, probably measurable in terms of rate of oxidation. One side develops more rapidly than the other, inhibiting more or less completely the growth of equivalent structures on the slower growing side. When twinning occurs, the two severed halves undergo complete regulation. Equilibrium at separation must be extremely delicate and minor factors may decide whether mirror-imaging will occur or not.

When we consider that in embryonic development the eye appears earlier than the appendage buds, it is not surprising that we should find mirror-imaging in eye dominance occurring more frequently than in handedness. The fact that all twins who showed any mirror-imaging in handedness, also showed reversal in eye dominance, should be expected, in view of the theory that an individual's dextrality depends upon which side of the brain is superior.

Contrary to the findings of Newman[5], mirror-imaging was observed as frequently in twins showing the greatest intra-pair physical and mental similarities, as in those showing the greatest intra-pair differences. Case XX, our only pair showing complete mirror-imaging in handedness, is among the most similar pairs in physical and mental traits, while no mirror-imaging was observed in Case III, which shows more than average intra-pair mental and physical differences. It is of interest to note that in Case XX, which showed complete mirror-imaging in handedness, the father is left-handed, also the maternal grandmother, and two maternal uncles. Case XIII, which shows partial mirror-imaging in handedness, has an *LLL* sib. I venture to suggest that possibly in families where both left- and right-handed individuals occur frequently, the chances of a set of monozygotic twins showing partial or complete mirror-imaging in this respect is greater than in families which are very predominantly right-handed or left-handed, because in ambidextrous individuals the two sides of the body are more evenly balanced, and therefore unusual conditions during embryonic development would be more likely to change the normal expression of dextrality than in natural strongly biased individuals.

Whatever may be the causes for mirror-imaging of certain traits in some pairs of monozygotic twins, such a phenomenon in itself does not disprove the fact that the traits, under normal conditions, have certain definite modes of inheritance.

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A Glossary Of Genetic Terms

GENETICS has developed so rapidly that many terms in common use in genetic literature are not yet incorporated in the dictionaries. Many people who are interested in heredity are bothered by such words, for which no definition can conveniently be found. For this reason, it is proposed to publish occasionally a glossary of terms which would not be readily understood and which are not to be found except in new unabridged dictionaries. It is realized that these definitions will probably not meet with universal approval and comments and suggestions will be welcomed.

AUTOSOMAL—Pertaining to any chromosome except the sex chromosomes.

ALLELOMORPH—Mendelian characters are inherited in alternative pairs, or in alternative series. These alternative genes are called allelomorphs. Examples: Albinism (recessive), Normal pigmentation (dominant); Horns (recessive), Hornlessness (dominant).

BACKCROSS—Cross of a hybrid to one of the parental forms.

CHROMOSOMES—Tiny dark-staining bodies visible in the nucleus of the cell at the time of cell-division. The number of chromosomes in any species is usually constant. The chromosomes carry the genes, linearly arranged, which control the development of Mendelian characters.

DENTINE—A calcareous material of similar composition to bone, but harder and denser, which composes the principal mass of a tooth; ivory. It consists of a matrix containing numerous minute parallel tubules (the *dentinal tubules*), which open into the pulp cavity and contain, during life, processes (called *dentinal fibers*), of the cells of the pulp.

DIZYGOTIC—Originating from two fertilized eggs. Dizygotic twins are genetically no more similar than ordinary brothers and sisters.

DOMINANT—A character possessed by one of the parents of a hybrid, which appears in the hybrid to the exclusion of the contrasted character from the other parent (the recessive). Thus in a cross of green- and yellow-seeded peas the first generation has yellow seeds. Yellow is dominant and green is recessive, being transmitted but not appearing in the presence of the factor for yellow.

FACTOR—Same as *Gene*.

F_1—(Pronounced eff-one). The first filial generation. The offspring of a given mating.

F_2—The second filial generation. Produced by intercrossing or self-fertilizing the F_1. The inbred grandchildren of a given mating.

HORMONE—The active principle secreted by a ductless gland, or other chemical controller of physiological activity produced by an organism.

GENE—(1) The unit of inheritance, which is transmitted in the germ cells, and which by interaction with the genic and cytoplasmic complex controls the development of a character. The genes are arranged linearly in the chromosomes. (2) "The physical basis of heredity"—or more figuratively, the atom of the genetic molecule.

HETEROZYGOUS—Containing both genes of an allelomorphic pair, or two genes of an allelomorphic series. Heterozygous individuals generally resemble the individuals homozygous for the dominant character, but they transmit the recessive to half their offspring.

FOLLICULAR HORMONE—A hormone formed by the Graffian follicles of the ovary. One of the female sex hormones.

HOMOZYGOUS—(1) An organism formed by like germ cells; (2) An organism is said to be homozygous for a given character when all the germ cells transmit identical genes for this character. This is the most frequently used meaning of the term.

MONOZYGOTIC—Originating from a single fertilized egg cell, which in the course of subsequent development has given rise (by fission) to two or more individuals. Twins (or triplets, etc.) of such origin are, barring mutations, genetically identical.

MUTATION—A sudden variation in an inherited character.

RECESSIVE—See *Dominant*.

SEGREGATION—Separation of allelomorphic genes at meiosis.

SEX-LINKED—Applied to characters carried on the sex-chromosomes—characterized by typical peculiarities in inheritance as a result of this fact.

ZYGOTE—An organism produced by the union of two germ cells.

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